SOME OBSERVATIONS ON AN OPERANT IN THE OCTOPUS

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Operant behavior has been successfully demonstrated in all species of mammals and birds for which a serious attempt has been made. Comparatively little attention has been paid to invertebrate species. This paper reports preliminary exploration of the behavior of the octopus (*O. vulgaris.* Lamark) to see whether components of its behavior could be found which fulfill the definitive requirements necessary to identify them as operants. The octopus has the advantage over most invertebrate species in that it has well-developed motor behavior of a nature which makes the selection of an arbitrary, objectively recorded response quite easy. In addition, Young and Boycott (1955) describe behavior in the octopus which is almost certainly operant in nature, i.e., not elicited, but maintained by its consequences. One reason for interest in this problem is that the octopus belongs to a phylum (Molusca) which has evolved independently of the pathway which leads to the vertebrates since Cambrian times (some 500 million years ago). If the phenomena of operant behavior are to be found in the octopus as well as in the vertebrate species studied, then these phenomena probably are of very general biological significance.

Three octopuses have been studied. All three were trained to pull a lever which led to the delivery of food. In two, reasonably consistent lever-pulling behavior was maintained until extinction; only partial success was obtained with the third octopus.

METHOD

Subjects were three octopuses (O. vulgaris), each weighing 500 grams, designated for identification purposes Albert, Bertram, and Charles. Each lived in its own tank of circulating sea water from which it was never removed during the experiments. The tanks of Albert and Charles were 4 feet 6 inches long by 2 feet 6 inches wide, and contained a depth of about 2 feet 6 inches of sea water. The tank of Bertram was 6 feet long and 2 feet 3 inches wide, and contained a depth of 2 feet 6 inches of sea water. At one end of each tank at the bottom were two or three bricks, which the octopus arranged to make a house. The undisturbed octopus spent almost all its time sitting in its house, "looking" out with one eye.

The lever was 1/4-inch brass rod which entered the water vertically and reached to within about 3 inches of the bottom. It was pivoted at a board which was rested across the top of the tank during an experiment. The pivot permitted the lever to be moved in only a single plane; but movement in either direction in that plane activated a light precision switch.[1] Operation of the switch led to illumination of a lamp which in definitive experiments was arranged to shine vertically into the water from above at the end of the tank opposite to that of the "house" of the octopus (the "far" end of the tank). The lever was arranged about the middle of the tank, somewhat nearer the far end. Only one lever and light assembly was used, the whole being moved from tank to tank for experiments on the various octopuses.

[1] "Acro" switch.

The response was movement of the lever so that the lamp lighted. Reinforcement was delivery of a small piece of fish about one-tenth of a filleted 3-inch sardine. The fish was on a nylon line with a small glass sinker.

PROCEDURE

The animals were deprived of food a day, and then responses were shaped as follows:

1) Taking the fish from the line when presented close by, moving up and down, in the beam of the light.

2) Swimming to the far end of the tank and taking the fish when presented in the beam of the light.

3) Approach to the lever.

4) Finally operation of the lever.

A similar shaping procedure was followed for all three octopuses. The following representative account gives in detail the sequence used with Bertram; the sequences used in the other two animals did not differ in any important particulars.

Day 1 No food. Previous to this the octopus had been fed with "several" small crabs per day.

Day 2 Took pieces of fish from line when presented 10-20 centimeters away in light beam.

Day 3 Octopus took total of nine pieces of fish over 5-hour period, starting each time from "house." First piece was presented 20 centimeters away, but remaining eight presented about middle of tank (i.e., about 80 centimeters away).
Initially, animal took fish only when it had been presented about 15 minutes, but last three were taken in 2-5 minutes.

Day 4 Eight pieces of fish taken over 6 hours. First three taken from positions intermediate between middle and far end of tank, remaining five from far end. Animal started from house each time. Last four were taken within 1 minute of presentation.

Day 5 Took five pieces of fish, each with 1 minute of presentation, from far end of tank on each of four occasions through day (total, 20 pieces of fish).

Day 6 Took 10 pieces of fish in single session; required to return to house between presentations.

Day 7 Lever introduced. Octopus ignored lever except to avoid touching it when swimming by.

Day 8 Like Day 7.

Day 9 Small piece of rubber tubing put around lower end of lever, to provide what was hoped would be more attractive surface for octopus tentacles. Also attached to lower end of lever, by short piece of thread, was a small maltese cross. The stream of water responsible for circulation and aeration of water in the tank was directed towards the lever, causing the cross to dance and twirl. These additions to the lever were adequate to cause the octopus to approach the lever, whereupon a piece of fish was presented. After a few such approaches, it was possible to require that the lever be encircled by two or more tentacles before the fish was presented. On two occasions, obtained fish while still having tentacle around lever; pulled lever at this time and was promptly given second piece of fish. Encircled lever with tentacles (and was given fish) 22 times during period of 1 hour; on three of these occasions, actually operated the lever.

Day 10 et sec. Required to operate lever before fish was presented. When the lever was operated and the light came on, the light was then kept on by manual switch and the fish introduced at far end of tank. When the octopus came over and took the fish, the light was kept on a few more seconds. When the fish line was released—free of fish—by octopus, a stop watch was started and the time to the next lever operation noted. This cycle was continued until the animal had had 20 pieces of fish, or until more than 10 minutes elapsed between release of line and operation of lever. The octopus was given the opportunity of obtaining these 20 pieces of fish (two filleted sardines total) at each of two sessions, one in the morning and the other some 3-4 hours later in the afternoon. This was the only food obtainable by the octopus during the experiments.

RESULTS

All three octopuses obtained 40 reinforcements on several consecutive days without the latency between release of the fish line and operation of the lever exceeding 10 minutes on any occasion.

An attempt was made to reinforce lever-pulling by Albert intermittently on a small fixed-ratio schedule—two, then three (Table 1, Day 5). The first 10 reinforcements on this day were given on the *crf* procedure above described. The next 10 were given at every other lever-pull; each time the lever was operated the lamp lighted in the usual way and was kept lit until the octopus released the lever and moved to the far end of the tank. At this time, either the light was extinguished and timing to the next lever-pull started (following odd-numbered responses), or food was presented in the usual way. The animal completed 20 more lever-pulls under this procedure without any latency rising to 10 minutes. In the afternoon session, after reinforcement of the initial response, the ratio was raised to 3:1. Under this procedure, the animal obtained five more reinforcements (i.e., 15 lever-pulls), but the latencies progressively rose and, after the 16th response, reached 10 minutes, the arbitrary cut-off point. On Day 6, only a few responses (4) were not reinforced, and 19 reinforcements were obtained before a latency of 10 minutes occurred. *Crf* was reintroduced, and over the next 6 days (Table 1, Days 7–12) the animal made 260 consecutive responses each within 10 minutes of release of the fish line. On the 13th day, extinction was instituted; the lamp lit on a response and remained on until the octopus came to the far end of the tank; but it was then turned off without presentation of fish. In the a.m. session of Day 13, 20 responses were made without occurrence of a latency of more than 10 minutes; but in the afternoon session, only 13 were made before a 10-minute pause. On the 14th day, 15 and 9 responses were made before a 10-minute pause in the morning or afternoon sessions, respectively. Since this animal had made 260 consecutive responses without a latency exceeding 10 minutes when on *crf*, the repeated occurrences of these long latencies when reinforcement of the response was discontinued are evidences of operant extinction.

TABLE 1 : ALBERT

Day	Mean Latency*	Range	Remarks
4(am)	70	20–178	*crf***
4(pm)	48	6–220	*crf*
5(am)	30	11–48	*crf*: 10 responses
5(pm)	68	27–180	Alternate lever-pulls reinforced: 20 responses, 10 reinforced.
5(pm)	98	18–	Every 3rd response reinforced: 16 responses, 6 reinforced. Latency > 10 min on 17th.
6(am)	93	15–	21 responses. 6,8,9, & 12 not reinforced. Latency > 10 min on 22nd.
6(pm)	86	23–	*crf*: 15 responses. Latency > 10 min on 16th.
7(am)	49	5–132	*crf*
7(pm)	58	28–128	*crf*
8(am)	53	17–115	*crf*
8(pm)	48	21–73	*crf*
9(am)	41	12–165	*crf*
9(pm)	109	20–327	Alternate lever-pulls reinforced: 40 responses, 20 reinforced.
10(am)	68	18–497	*crf*
10(pm)	74	11–180	*crf*
11(am)	62	23–130	*crf*
11(pm)	86	17–369	*crf*
12(am)	46	19–160	*crf*
12(pm)	40	20–133	*crf*
13(am)	194	33–375	Ext†
13(pm)	108	20–	Ext: 12 responses. Latency > 10 min on 13th.
14(am)	113	2–	Ext: 15 responses. Latency > 10 min on 16th.
14(pm)	150	50–	Ext: 9 responses. Latency > 10 min on 10th.

* From release of fish line to operation of lever, in seconds. Mean of 20 except where otherwise indicated.

** Food presented each time lever operated.

† Extinction: no fish given.

On Days 14 through 17, Bertram made 120 consecutive responses; the mean latency fell to less than 30 seconds on Days 16 and 17 (Table 2). Reinforcement was then discontinued; 79 responses were made on Days 17 (p.m.), 18, and 19, until a latency of 10 minutes occurred. On Day 20, no response occurred in 20 minutes, again giving clear evidence of operant extinction. There was some "spontaneous recovery" on Day 21, but a performance of 20 consecutive responses without more than a 10-minute latency was not achieved.

TABLE 2 : BERTRAM

Day	Mean Latency*	Range	Remarks
10(pm)	40	16–121	*crf***
11(am)	18	5–45	*crf*
12(am)	38	4–170	*crf*
12(pm)	41	6–125	*crf*
13(am)	57	16–150	*crf*
13(pm)	56	10–120	*crf*: 5 responses.
13(pm)	69	37–380	Ext†: 15 responses.
13(pm; later)	90	12–	Ext: 16 responses. Latency > 10 min on 17th.
13(pm; still later)	98	20–	Ext: 11 responses. Latency > 10 min on 12th.
13(pm; yet again later)	110	40–	*crf*: 5 responses. Latency > 10 min on 6th.
14(am)	76	29–	Ext: 15 responses. Latency > 10 min on 16th.
14(pm)	38	5–82	*crf*
15(am)	54	20–129	*crf*
15(pm)	56	30–161	*crf*
16(am)	22	7–60	*crf*
16(pm)	22	12–45	*crf*
17(am)	20	8–43	*crf*
17(pm)	46	25–75	Ext.
18(am)	72	46–108	Ext.
18(pm)	46	6–245	Ext.
19(am)	165	30–	Ext: 19 responses. Latency > 10 min on 20th.
20(am)	–	–	"Ext.": Latency to 1st response > 10 min.
20(pm)	155	61–	Ext: 3 responses. Latency > 10 min on 4th.
21(am)	171	26–	Ext: 7 responses. Latency > 10 min on 8th.
21(pm)	61	10–	Ext: 6 responses. Latency > 10 min on 7th.

* From release of fish line to operation of lever, in seconds. Mean of 20 except where otherwise indicated.

** Food presented each time lever operated.

† Extinction: no fish given.

TABLE 3 : CHARLES

Day	Mean Latency*	Range	Remarks
7(am)	94	10–490	*crf***
7(pm)	129	25–	*crf*: 10 responses. Latency > 10 min on 11th.
8(am)	81	15–287	*crf*
8(pm)	25	25–	*crf*: 1 response. Latency > 10 min on 2nd.
9(am)	49	7–218	*crf*
9(pm)	82	17–383	*crf*
10(am)	93	17–417	*crf*
10(pm)	98	15–570	*crf*
11(am)	Broke Lever		
11(pm)	101	5–385	*crf*
12(am)	57	10–	*crf*: 14 responses. Latency > 10 min on 15th.
12(pm)	124	35–	*crf*: 14 responses. Latency > 10 min on 15th.

* From release of fish line to operation of lever, in seconds. Mean of 20 except where otherwise indicated.

** Food presented each time lever operated.

Charles was more capricious and effective, and sustained control was not achieved. The best series was achieved on Days 9 and 10, when 80 consecutive responses were made without a latency in excess of 10 minutes. The behavior of this animal, however, differed from that of the other two in a number of interesting respects.

1) Whereas Albert and Bertram gently operated the lever while free-floating, Charles anchored several tentacles on the side of the tank and others around the lever and applied great force. The lever was bent a number of times, and on the 11th day was broken, leading to a premature termination of the experiment.

2) The light, suspended a little above the level of the water, was not the subject of much "attention" by Albert or Bertram; but Charles repeatedly encircled the lamp with tentacles and applied considerable force, tending to carry the light into the tank. This behavior is obviously incompatible with lever-pulling behavior.

3) Charles had a high tendency to direct jets of water out of the tank; specifically, they were in the direction of the experimenter. The animal spent much time with eyes above the surface of the water, directing a jet of water at any individual who approached the tank. This behavior interfered materially with the smooth conduct of the experiments, and is, again, clearly incompatible with lever-pulling.

The activities described in 2 and 3 above became progressively more predominant as the experiments proceeded; and on Days 20 and 21 they had become so predominant as to lead to cessation of lever-pulling behavior before 20 reinforcements had been obtained. The variables responsible for the maintenance and strengthening of the lamp-pulling and squirting behavior in this animal were not apparent.

DISCUSSION

The behavior of lever-pulling in these experiments showed the following characteristics of an operant:

1) It was found possible to differentiate the response by deliberate shaping.

2) The occurrence of the response was maintained by its consequences (the presentation of fish).

3) The tendency of the response to occur fell when it was no longer reinforced.

The attempt to establish the response as a free operant, permitting continuous observation of its frequency of occurrence, was not successful. At least two factors contributed to this failure:

1) Once an octopus has taken firm grip of an object, it has a high tendency to retain a firm grip. In its natural environment, the train of events following seizure of an object has probably usually only one of two conclusions: either the eating of the object, or its release to pursue another object. In these experiments, once an octopus had operated the lever, it tended to maintain the lever in the operated state, and could only be dislodged by the provision of an alternative object (light beam and dangling fish). It was further necessary to make sure these objects were presented too far from the lever for the octopus to be able to reach them while still retaining possession of the lever. These measures were effective in obtaining a discontinuous response, but only at the expense of severely reducing the possibility (and significance) of obtaining a "rate-of-occurrence" measure of the operant.

2) Only relatively short sequences of *crf* were presented before the attempt was made to introduce a fixed-ratio schedule of reinforcement.

CONCLUSION

The "law of effect" appears to operate in the octopus as in vertebrates. In view of the wide phylogenetic separation of these types of animals, these findings add to the evidence of the very general biological applicability of this law.

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